

Construction of the CHIPS-M prototype and simulations of a 10 kiloton module

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1 Introduction

CHIPS is an R&D experiment intending to produce large, low-cost water Cherenkov detectors that can be used to study long-baseline neutrino oscillations. Such detectors are traditionally constructed underground, incurring large civil engineering costs in order to excavate or renovate a suitable cavern. CHIPS instead proposes to construct **CH**erenkov detectors in **Mine Pits**, by submerging a detector at the bottom of deep bodies of water on the surface of the Earth.

In the summer of 2014, a small 26 ton prototype detector was deployed in a former iron quarry in Northern Minnesota, 7 mrad off-axis from the NuMI beam. This poster describes the construction and deployment of this prototype, and simulations of a larger 10 kton module.

2 CHIPS experiment

As well as reducing engineering costs, constructing the detector in a lake will provide the detector with sufficient overburden. For a 40 kton detector at a depth of 40 m the cosmic ray event rate is estimated to lead to a mean dead time per NuMI beam spill of 250 ns (or 2.5%)[1].

The detector is filled with filtered lake water, enclosed in a waterproof, opaque plastic geomembrane. The design attempts to use commercially available materials where possible: studies for the full-size modules are currently investigating the use of a “space frame” of interlocking tubes, and fibreglass panels used by radar dome manufacturers.

The experiment is located at the Wentworth 2W pit, near to Hoyte Lakes, Minnesota. A former iron quarry, the pit is 60 m deep and situated 7 mrad off-axis from Fermilab’s NuMI neutrino beam at a baseline of 712 km. This exposes CHIPS to a lower peak beam energy than MINOS (on-axis) but a higher flux compared to NOvA (14 mrad).

3 CHIPS-M

A 26 ton prototype detector, CHIPS-M (“Model”), was constructed during the summer of 2014 by a team largely made up of students and postdocs. CHIPS-M is an octagonal detector, 3.5 m tall by 3.2 m in diameter, comprising a rigid frame of aluminium stage truss and stainless steel unistrut surrounded by an opaque plastic geomembrane. The membrane is white on the outside and black on the inside (allowing for a possible veto region outside the main volume) and is tightly clamped between aluminium batten bars and the main frame of the detector with waterproof tape in between.

The detector is instrumented with five DOMs: Digital Optical Modules[2] consisting of a pressure sphere containing a 10” photomultiplier tube and electronics for high voltage supply, data acquisition, etc., borrowed from the IceCube experiment. These are attached to the frame using a pivoting mount that has floats attached to point the DOMs’ photocathodes at a 45° angle to the beam. IceCube’s DOMs are designed to point downwards, so this angle was chosen to reduce the risk of the optical gel shearing compared to facing the beam directly. GPS timing is used so that timestamps from the DOMs can be compared to NuMI beam spills.

Two pressure cylinders containing cameras and environmental monitoring sensors are also present, one inside the detector and one outside. These proved invaluable in the deployment and filling of the detector.

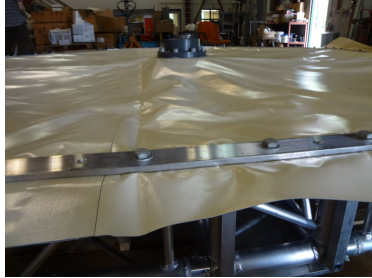


Figure 1: Aluminium batten bars which clamp the liner and waterproof tape to the frame

Figure 2: Top and bottom stage truss sections covered with liner and held apart by stainless steel unistrut

Figure 3: Two DOMs mounted at the top of the detector

The prototype is intended to test the suitability of the materials chosen, in particular their durability underwater and the performance of the liner and sealing tape. It will also provide indications as to how sophisticated a water filtration system is required in order to achieve acceptable water clarity in a 10 kton module. The detector will be retrieved and assessed in June 2015, fitted with additional PMTs (a flat panel of 3” tubes derived from KM3NeT’s 31-PMT optical module) and environmental sensors, and resubmerged for a second year of tests.

4 Data from CHIPS-M

CHIPS-M is submerged and has been taking data since the beginning of August, observing Cherenkov light primarily from cosmic ray muons (beam events are difficult to distinguish in a detector of this size). For these studies, an event is defined as a coincidence between the four DOMs at the top of the detector, with each hit above 5 photoelectrons and within 15ns of the first. The rate of these events is shown in Figure 4.

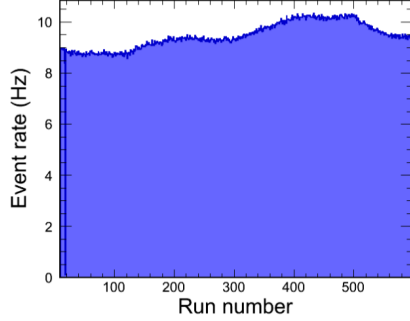


Figure 4: Rate of four DOM coincidences observed at CHIPS-M

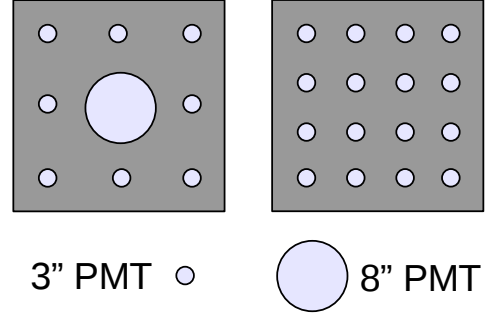


Figure 5: Schematic of two patterns that can be compared using the simulation

The DOMs also contain an LED flasher board. Studies into using this board to measure the water clarity over time are ongoing.

5 CHIPS-10

The intention of CHIPS is to design a 10 kton module for which construction could begin in 2016. The baseline design is a cylinder 25 m in diameter and 20 m high, constructed from tiling modules of fibreglass, or a spaceframe with panels of geomembrane liner. This would be constructed in layers before finally sealing together the walls and the top and sinking it to the bottom of the pit.

An advantage of such a design is that the full-size detector need not be constructed at once, but can be retrieved to add additional layers as funding and seasonal ice coverage allow. This also permits the detector to be redeployed in the future LBNF beam.

The 10 kton detector would have a cosmic ray veto region of outward facing PMTs, and be able to accommodate different types of PMT to operate as a test-bed for optical modules exposed to a real neutrino beam.

6 Simulations of CHIPS-10

A Geant4[3] simulation package has been written for CHIPS-10. Figure 6 shows a sample event display from this simulation. The package is based on the simulation tool for the

former LBNE water Cherenkov option, with a number of major additions to suit CHIPS design studies. In particular, it allows multiple types of PMT to be placed in the same detector, with photomultipliers arranged in any arbitrary repeating pattern on a square lattice, instead of a simple square array. This feature is illustrated in Figure 5.

The detector is also divisible into regions, with the PMT layout of each region specified separately. This enables the testing of layouts with, for example, a higher density of photomultipliers on the downstream region of the detector relative to the beam.

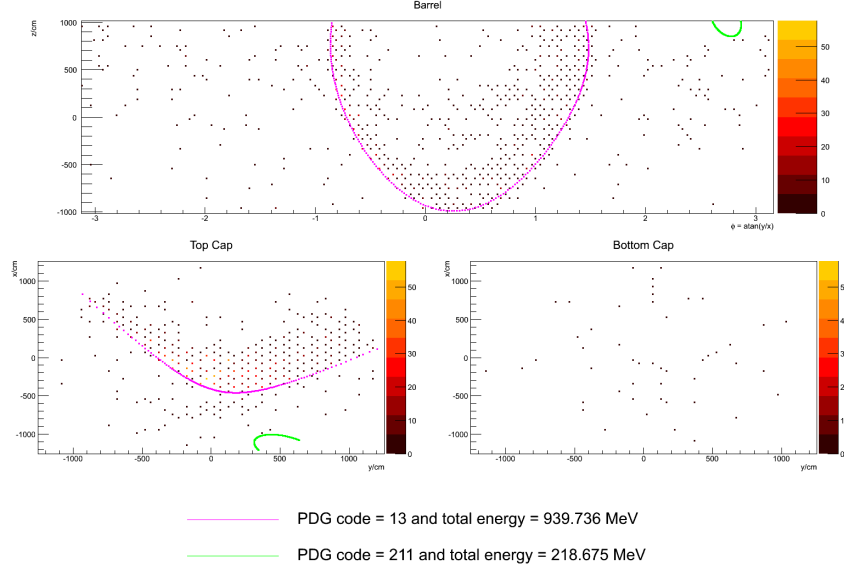


Figure 6: Event display with rings drawn based on MC truth information for a ν_μ CC interaction in a 10kton CHIPS detector. Two PMT types are placed in a diagonal pattern, with a total photocathode coverage of 10%.

7 Summary

During the summer of 2014, the CHIPS collaboration successfully constructed and deployed a small prototype water Cherenkov detector at the bottom of a 60 m deep pit in the NuMI beam. The detector has been taking daily cosmic runs and measuring the rate of coincident hits between DOMs, and has allowed tests of the water filtration system and environmental monitoring vessels. It will be retrieved in June 2015 to assess the durability of the detector structure and geomembrane liner.

Meanwhile, the design and simulation of a full 10kton module are underway, including features for complex PMT layouts to maximise the physics performance.

References

- [1] P. Adamson, J. A. B. Coelho, G. S. Davies, J. J. Evans, P. Guzowski, A. Habig, J. Hartnell and A. Holin *et al.*, arXiv:1307.5918 [physics.ins-det].
- [2] R. Abbasi *et al.* [IceCube Collaboration], Nucl. Instrum. Meth. A **601** (2009) 294 [arXiv:0810.4930 [physics.ins-det]].
- [3] S. Agostinelli *et al.* [GEANT4 Collaboration], Nucl. Instrum. Meth. A **506** (2003) 250.